THE AQUATIC PLANT COMMUNITY IN ARROWHEAD LAKE, ADAMS COUNTY, WISCONSIN DECEMBER 2006

Submitted by Reesa Evans

Adams County Land & Water Conservation Department

P.O. Box 287, Friendship, WI 53934
608-339-4268

THE AQUATIC PLANT COMMUNITY FOR ARROWHEAD LAKE
ADAMS COUNTY 2006

I. INTRODUCTION

An updated aquatic macrophytes (plants) field study of Arrowhead Lake was conducted during June 2006 by a staff member the Adams County Land and Water Conservatism Department and a staff member of the Tri-Lakes Management District. A previous quantitative vegetation study of Arrowhead Lake was done during July 2000 by the Wisconsin Department of Natural Resources.

Information about the diversity, density and distribution of aquatic plants is an essential component in understanding the lake ecosystem due to the integral ecological role of aquatic vegetation in the lake and the ability of vegetation to impact water quality (Dennison et al, 1993). This study will provide information useful for effective management of Arrowhead Lake, including fish habitat improvement, protection of sensitive areas, aquatic plant management, and water resource regulation. This data will be compared to the prior study results and also used for future studies, offering insight into any changes within the lake.

Ecological Role: Lake plant life is the beginning of the lake's food chain, the foundation for all other lake life. Aquatic plants and algae provide food and oxygen for fish and wildlife, as well as cover and food for the invertebrates that many aquatic organisms depend on. Plants provide habitat and protective cover for aquatic animals. They also improve water quality, protect shorelines and lake bottoms, add to the aesthetic quality of the lake, and impact recreation.

Characterization of Water Quality: Aquatic plants can serve as indicators of water quality because of their sensitivity to water quality parameters such as clarity and nutrient levels (Dennison et al, 1993).

Testing has shown that Arrowhead Lake has hard water. Lake water pH has ranged from 6.4 to 8.16. Hard water lakes tend to produce more fish and aquatic plants than soft water lakes.

Background and History: Arrowhead Lake is located in the Town of Rome, Adams County, Wisconsin. The impoundment is 350 surface acres in size. Maximum depth is 30', with an average depth of 8'. During the summer of 2006 when this aquatic plant survey was conducted, the lake was at slightly lower level than usual due to drought and very hot weather. The dam impounds Fourteen-Mile Creek downstream from the dams at Lower and Upper Camelot Lakes and Sherwood Lake, on its way to the Wisconsin River. There is a public boat ramp located on southwest side of the lake owned by The Adams County Parks Department, as well as a public swimming beach.

Arrowhead Lake is accessible off of State Highway 13 by turning west onto either Apache Avenue, then north on 15th Avenue or turning west on County D, then south onto 15th Ave. Heavy residential development around the lake is found along most of the lakeshore. The surface watershed is 39.88% residential; 30.06% woodlands; 11.66% outdoor recreation (mostly golf courses); 9.82% water; 4.9% industrial/commercial/governmental; and 3.68% open grassland. The ground watershed, which extends into Waushara County, has much irrigated and non-irrigated agriculture, except near to the lakes. There are endangered or

threatened resources in the watershed which include the Karner Blue Butterfly, the Persius Dusky Wing Butterfly; the Red-Shouldered Hawk; and the natural communities of northern sedge meadow and shrub-carr. There are no reported archeological or historical sites in the Arrowhead Lake surface watershed.

A fishery inventory in October 2004 revealed that walleye and largemouth bass are abundant in Arrowhead Lake; bluegills and white suckers are common; yellow perch and northern pike are scarce.

Soils in the Arrowhead Lake surface watershed are sands of various slopes. Such soils tend to be excessively-drained, with infiltration of water being rapid to very rapid, and permeability also high. Such soils also usually have a low water-holding and low organic matter content, thus making them difficult to establish vegetation on. These soils tend to be easily eroded by both water and wind.

Efforts at controlling aquatic plant growth have included both chemical treatments and mechanical harvesting.

		Aquatic Herbicicides Applied to Arrowhead Lake				
Year	**Copper (lbs)**	**Cutrine (gal)**	**Aquathol (gal)**	**Hydrothol (gal)**	**Diquat (gal)**	**Rodeo (gal)**
1981	1400					
1982	125					
1983	150		7		6	
1984	75		14	52		
1985	300		41.5		15	
1986	610		30		10	
1987	350		5		5	
1988	375		22		10	
1989	1050					
1990	200				3	0.75
1991	475		5		3	
1992	300		10		10	
1993			10		20	
1994	785		6.25		3.75	
1995	725		24		9	
1996		55	11			11
1997		65				
1999			5		5	
2000			15		15	
Total	6920 lbs	121 gal	205.75 gal	52 gal	113.75 gal	11.75 gal

Both copper in pounds and cutrine in gallons added copper to Arrowhead Lake. Copper is an element and does not degrade any further. Copper is known to harm native mollusks (clams, mussels, snails) and invertebrates that serve as food for the fish. Approximately 1754 pounds of copper now reside in the sediments of Arrowhead Lake. Hydrothol, added to Arrowhead Lake in 1984, has been implicated in damage to young fish.

Mechanical harvesting of aquatic plants in Arrowhead Lake started in 1995 and has continued through 2006. The chart below shows the pounds of aquatic plant removed through mechanical harvesting through 2006. For 2005 and 2006, plant

samples were taken to a laboratory to be tested for the amount of phosphorus in milligrams per kilogram of aquatic plants. This is also shown on the chart below.

Year	Pounds Harvested	Phosphorus Removed in Pounds
1995	37,000	NA
1996	98,000	NA
1997	85,000	NA
1998	214,000	NA
1999	221,100	NA
2000	274,000	NA
2001	328,000	NA
2002	54,600	NA
2003	313,000	NA
2004	296,000	NA
2005	55,000	281.88
2006	4,188,000	1261.38
total	6,163,700	1543.26

An aquatic plant survey was conducted by WDNR staff in 2000. This survey found that that the plant-like algae, *Chara* spp (muskgrass), was the most frequently-occurring aquatic "plant" species in Arrowhead Lake, closely followed by *Potamogeton pusillus* (small pondweed). No species occurred at more than 50% frequency. *Chara spp* also had the highest density, again followed by *Potamogeton pusillus.* On the lake overall, only these two occurred at more than average density. Although three invasives, *Myriophyllum spicatum* (Eurasian watermilfoil), *Phalaris arundinacea* (Reed Canarygrass), and *Potamogeton crispus* (Curly-Leaf Pondweed) were found in 2000, none of them occurred at high frequency, density or dominance.

Since the 2000 plant survey, zebra mussels were found in Arrowhead Lake. The process of evaluating the level of infestation is still ongoing. Plates were hung in various portions of the lake during 2006 and divers examined some of the underwater dam structures, looking for zebra mussel accumulations.

II. METHODS

Field Methods

Both the 2000 and 2006 studies were based on the rake-sampling method developed by Jessen and Lound (1962), using stratified random transects. The shoreline was divided into 19 equal sections, with one transect placed randomly within each segment, perpendicular to the shoreline. The same transects were used for both studies.

One sampling site was randomly chosen in each depth zone (0-1.5'; 1.5'-5'; 5'-10'; 10'-20') along each transect. Using long-handled, steel thatching rakes, four rake samples were taken at each site. Samples were taken from each quarter around the boat. Aquatic species present on each rake were recorded and given a density rating of 0-5.

A rating of 1 indicates the species was present on 1 rake sample.

A rating of 2 indicates the species was present on 2 rake samples.

A rating of 3 indicates the species was present on 3 rake samples.

A rating of 4 indicates the species was present on 4 rake samples.

A rating of 5 indicates that the species was abundantly present on all rake samples.

A visual inspection and periodic samples were taken between transects to record the presence of any species that didn't occur at the raking sites. Gleason and Cronquist (1991) nomenclature was used in recording species found.

Shoreline type was also recorded at each transect. Visual inspection was made of 50' to the right and left of the boat along the shoreline, 35' back from the shore (so total view was 100' x 35'). Percent of land use within this rectangle was visually estimated and recorded.

Data Analysis:

The percent frequency (number of sampling sites at which it occurred/total number of sampling sites) of each species was calculated. Relative frequency (number of species occurrences/total of all species occurrences) was also calculated. The mean density (sum of species' density rating/number of sampling sites) was calculated for each species. Relative density (sum of species' density/total plant density) was also calculated. "Mean density where present "(sum of species' density rating/number of sampling sites at which the species occurred) was calculated. Relative frequency and relative density results were summed to obtain a dominance value. Species diversity was measured by Simpson's Diversity Index.

The Average Coefficient of Conservatism and Floristic Quality Index were calculated as outlined by Nichols (1998) to measure plant community disturbance. A coefficient of Conservatism is an assigned value between 0 and 10 that measures the probability that the species will occur in an undisturbed habitat. The Average Coefficient of Conservatism is the mean of the coefficients for the species found in the lake. The coefficient of conservatism is used to calculate the Floristic Quality Index, a measure of a plant community's closeness to an undisturbed condition.

To measure the quality of the plant community, an Aquatic Macrophyte Index was determined using the method developed by Nichols et al (2000). This measurement looks at the following seven parameters and assigns each of them a number on a scale of 1-10: maximum depth of plant growth; percentage of littoral zone vegetated; Simpson's diversity index; relative frequency of submersed species; relative frequency of sensitive species; taxa number; and relative frequency of exotic species. The average total for the North Central Hardwoods lakes and impoundments is between 48 and 57.

III. RESULTS

Physical Data

The aquatic plant community can be impacted by several physical parameters. Water quality, including nutrients, algae and clarity, influence the plant community; the plant community in turn can modify these boundaries. Lake morphology, sediment composition and shoreline use also affect the plant community.

The trophic state of a lake is a classification of water quality (see Table 1). Phosphorus concentration, chlorophyll a concentration and water clarity data are collected and combined to determine a trophic state. **Eutrophic lakes** are very productive, with high nutrient levels and large biomass presence. **Oligotrophic lakes** are those low in nutrients with limited plant growth and small fisheries. **Mesotrophic lakes** are those in between, i.e., those which have increased production over oligotrophic lakes, but less than eutrophic lakes; those with more biomass than oligotrophic lakes, but less than eutrophic lakes; those with a good and more varied fishery than either the eutrophic or oligotrophic lakes.

The limiting factor in most Wisconsin lakes, including Arrowhead Lake, is phosphorus. Measuring the phosphorus in a lake system thus provides an indication of the nutrient level in a lake. Increased phosphorus in a lake will feed algal blooms and also may cause excess plant growth. **The 2004-2006 summer average phosphorus concentration in Arrowhead Lake was 24.33 ug/ml.** This is below the average for impoundments. This concentration suggests that Arrowhead Lake is likely to have some nuisance algal blooms, but not as frequently as many impoundments. This places Arrowhead Lake in the "good" water quality section for impoundments, and in the "**mesotrophic**" level for phosphorus.

Chlorophyll concentrations provide a measurement of the amount of algae in a lake's water. Algae are natural and essential in lakes, but high algal populations can increase water turbidity and reduce light available for plant growth. **The 2004-2006 summer average chlorophyll concentration in Arrowhead Lake was 8.58 ug/ml.** These chlorophyll results place Arrowhead Lake at the "**mesotrophic**" level for chlorophyll a results.

Water clarity is a critical factor for plants. If aquatic plants receive less than 2% of the surface illumination, they won't survive. Water clarity can be reduced by turbidity (suspended materials such as algae and silt) and dissolved organic chemicals that color or cloud the water. Water clarity is measured with a Secchi disk. **Average summer Secchi disk clarity in Arrowhead Lake in 2004-2006 was 6.15'.** This is good water clarity, putting Arrowhead Lake into the "**mesotrophic**" category for water clarity.

It is normal for all of these values to fluctuate during a growing season. They can be affected by human use of the lake, by summer temperature variations, by algae growth & turbidity, and by rain or wind events. Phosphorus tends to rise in early summer, than decline as late summer and fall progress. Chlorophyll a tends to rise in level as the water warms, then decline as autumn cools the water. Water clarity also tends to decrease as summer progresses, probably due to algae growth, then improve as fall approaches.

Table 1: Trophic States

Trophic State	Quality Index	Phosphorus (ug/ml)	Chlorophyll a (ug/ml)	Sechhi Disk (ft)
Oligotrophic	Excellent	<1	<1	>19
	Very Good	1 to 10	1 to 5	8 to 19
Mesotrophic	Good	**10 to 30**	**5 to 10**	**6 to 8**
	Fair	30 to 50	10 to 15	5 to 6
Eutrophic	Poor	50 to 150	15 to 30	3 to 4
Arrowhead Lake		**24.33**	**8.49**	**6.15'**

According to these results, Arrowhead Lake scores as **"mesotrophic"** in the three general parameters often used to gauge lake water health. With such phosphorus readings and chlorophyll a readings, moderate plant growth and occasional algal blooms would be expected.

A 2000 groundwater study done by UW-Stevens Point indicated that drawdowns in Camelot and Sherwood Lakes resulted in increases of 3000% in ammonium and 700% in reactive phosphorus in part of Arrowhead Lake. Such an increase in these factors may also stimulate aquatic plant growth and would most certainly increase algae growth. A 2002 Limnological Investigation by the U.S. Army

Corps of Engineers revealed that chlorophyll a and total phosphorus increased in Arrowhead Lake, compared to Camelot and Sherwood Lakes, suggesting internal loading of phosphorus. However, Secchi transparency was greater in Arrowhead Lake.

Lake morphology is an important factor in distribution of lake plants. Duarte & Kalff (1986) determined that the slope of a littoral zone could explain 72% of the observed variability in the growth of submerged plants. Gentle slopes support higher plant growth than steep slopes (Engel 1985).

Arrowhead Lake is a narrow lake that lies at the end of a series of lakes that are originally fed by a very large, multi-county stream system. Much of the lake is shallow, although there are some areas of steeper drop-offs within the lake near the dam. With good water clarity and shallow depths, plant growth may be favored in much of Arrowhead Lake, since the sun reaches much of the sediment to stimulate plant growth.

Sediment composition can also affect plant growth, especially those rooted. The richness or sterility and texture of the sediment will determine the type and abundance of macrophyte species that can survive in a particular location.

Table 2: Sediment Composition—Arrowhead Lake

Sediment	Type	Zone 1	Zone 2	Zone 3	Zone 4	Overall
Hard	Sand	59.38%	75.00%	71.88%	90.91%	70.34%
	Sand/Rock	21.88%	3.13%			6.78%
	Rock	6.24%				1.69%
Mixed	Sand/Peat		3.12%	6.25%	9.09	4.24%
	Sand/Peat/Rock		3.13%			.85%
Soft	Muck	12.50%	12.50%	15.63%		6.78%
	Peat		3.12%			.85%

Most of the sediment in Arrowhead Lake is hard, with little natural fertility and low available water holding capacity. Although such sediment may limit growth, most hard sediment sites in Arrowhead Lake were vegetated. 90.8% sample sites were vegetated in Arrowhead Lake, no matter what the sediment. Most sites without vegetation appeared to have been hand-harvested.

Shoreline land use often strongly impacts the aquatic plant community and thus the entire aquatic community. Impacts can be caused by increased erosion and sedimentation and higher run-off of nutrients, fertilizers and toxins applied to the land. Such impacts occur in both rural and residential settings.

Native herbaceous vegetation was the shoreline cover with highest percent of frequency (56.67%), but wooded vegetation had the highest coverage amount (30.00%), although cultivated lawn was close behind with 29% coverage. Some type of native vegetated shoreline covered 48.00% of the lake shoreline. But disturbed sites, such as those with traditional lawn, rock/riprap, hard structures and pavement, were also frequent, covering over 40.34% of the shoreline. Bare unprotected or eroded soil was found (11.66% coverage). Overall, 52.00% of Arrowhead Lake's shore has some kind of disturbed situation.

Table 3: Shoreland Land Use—Arrowhead Lake

Natural	Type	2006 Frequency	2000 Frequency	2006 Coverage	2000 Coverage
Vegetated	Herbaceous	81.25%	56.67%	18.13%	2.00
Shoreline	Shrub	25.00%	16.67%	2.81%	1.67%
	Wooded	71.88%	30.00%	28.59%	30.00%
Distrubed	Bare Sand/Eroded	46.87%	33.33%	12.19%	11.66%
Shoreline	Cultivated Lawn	40.63%	46.67%	16.56%	29.00%
	Hard Structure	53.13%	10.00%	7.97%	2.00%
	Pavement/Gravel	62.50%	10.00%	2.19%	3.83%
	Rock Riprap	50.00%	26.67%	11.56%	5.50%

Although there has been an increase in herbaceous cover since 2000 and a decrease in cultivated lawn coverage, both hard structure and rock riprap have increased substantially.

Macrophyte Data

SPECIES PRESENT

Of the 28 species found in Arrowhead Lake, 25 were native and 3 were exotic invasives. In the native plant category, 9 were emergent, 3 were free-floating plants, and 13 were submergent species. Three exotic invasives, *Myriophyllum spicatum* (Eurasian Watermilfoil), *Phalaris arundinacea* (Reed Canarygrass) and *Potamogeton crispus* (Curly-Leaf Pondweed) were found.

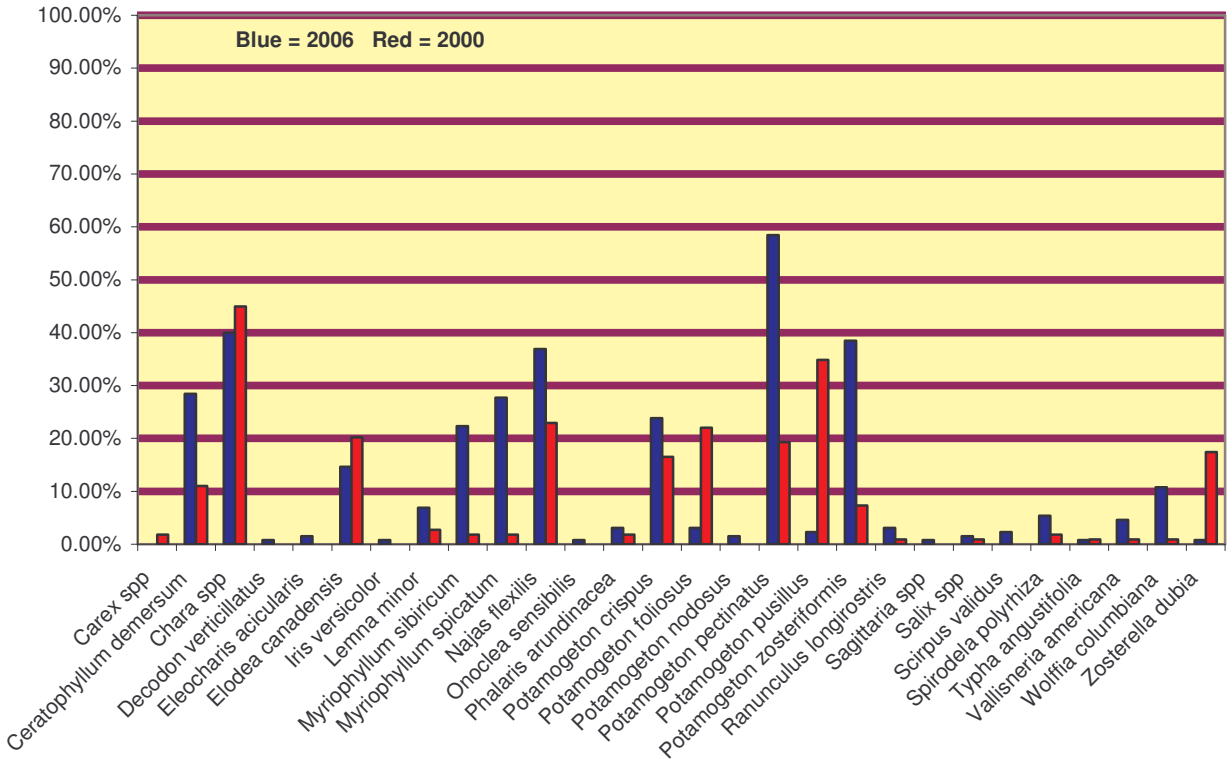
Table 4—Plants Found in Arrowhead Lake, 2006

Scientific Name	Common Name	Type	Found in 2000
Ceratophyllum demersum	Coontail	Submergent	x
Chara spp	Muskgrass	Submergent	x
Decodon vertticillatus	Swamp Loosestrife	Emergent	
Eleocharis acicularis	Needle Spikerush	Emergent	
Elodea canadensis	Waterweed	Submergent	x
Iris versicolor	Blue-Flag Iris	Emergent	
Lemna minor	Lesser Duckweed	Free-Floating	x
Myriophyllum sibiricum	Northern Milfoil	Submergent	x
Myriophyllum spicatum	Eurasian Watermilfoil	Submergent	x
Najas flexilis	Bushy Pondweed	Submergent	x
Onoclea sensibilis	Sensitive Fern	Emergent	
Phalaris arundinacea	Reed Canarygrass	Emergent	x
Potamogeton crispus	Curly-Leaf Pondweed	Submergent	x
Potamogeton foliosus	Leafy Pondweed	Submergent	x
Potamogeton illinoensis	Illinois Pondweed	Submergent	
Potamogeton nodusus	Long-Leaf Pondweed	Submergent	
Potamogeton pectinatus	Sage Pondweed	Submergent	x
Potamogeton pusillus	Small Pondweed	Submergent	x
Potamogeton zosteriformis	Flat-Stem Pondweed	Submergent	x
Ranunculus longirostris	Water Buttercup	Emergent	x
Sagittaria spp	Arrowhead	Emergent	
Salix spp	Willow	Emergent	x
Scirpus validus	Soft-Stem Bulrush	Emergent	
Spirodela polyrhiza	Greater Duckweed	Free-Floating	x
Typha angustifolia	Narrow-Leaf Cattail	Emergent	x
Vallisneria americana	Water Celery	Submergent	x
Wolffia columbiana	Watermeal	Free-Floating	x
Zosterella dubia	Water Stargrass	Submergent	x

FREQUENCY OF OCCURRENCE

Potamogeton pectinatus was the most frequently-occurring plant in Arrowhead Lake in 2006 (58.46% frequency). No other species reached a frequency of 50% or greater. Next closest in frequency of occurrence were *Chara* spp (40.00%), *Potamogeton zosteriformis* (38.46%), and *Najas flexilis* (36.92%). In 2000, no species reached a frequency of 50% of greater in the lake overall, although *Chara* spp had an overall occurrence frequency of 44.95%.

Chart 1: Occurrence Frequency



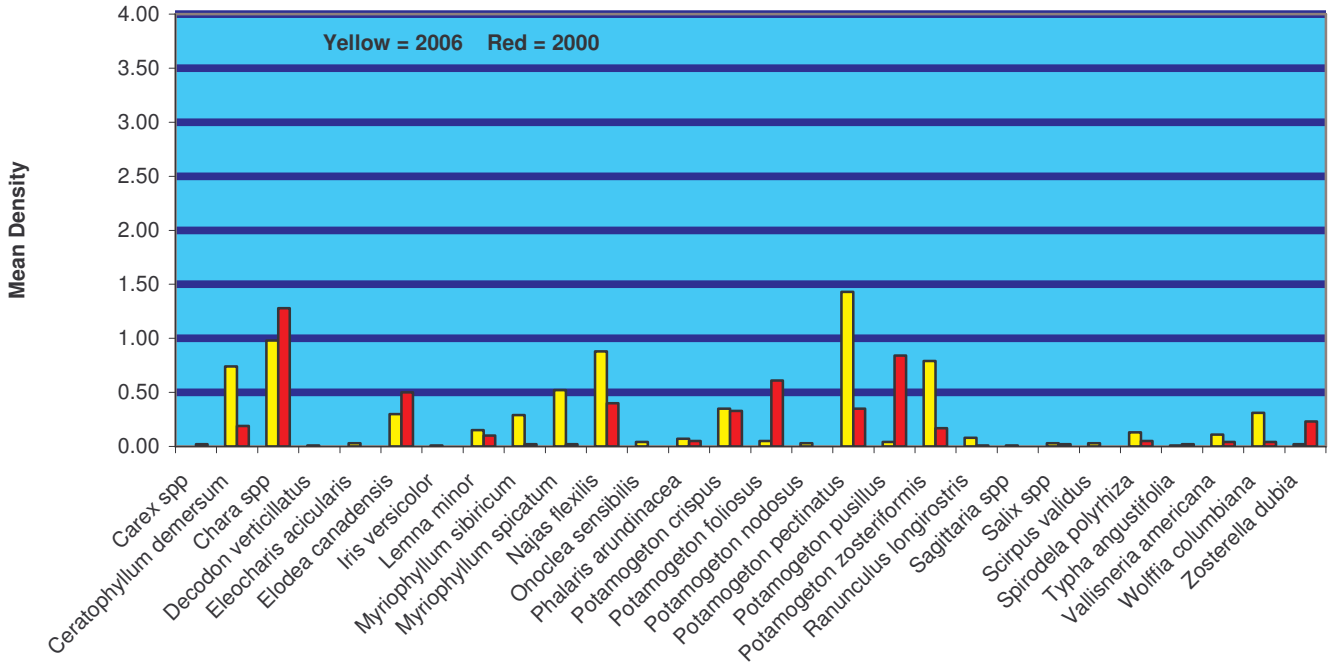
Filamentous algae were found at 22.88% of the sample sites in 2006 and found at 15.6% of the sites in 2000.

DENSITY OF OCCURRENCE

Potamogeton pectinatus was also the densest plant in Arrowhead Lake, with a mean density of 1.43 (on a scale of 1 to 4). In the lake overall, none of the aquatic vegetation had a mean density of over 2.0, meaning none occurred at more than average. There were no species at more than average density in any of the depth zones either. The densest-occurring plant in Depth Zone 1 (0-1.5') was *Chara* ""(1.53). Densest in Depth Zone 2 (1.5'-5.0') was *Potamogeton nodosus* (1.91).

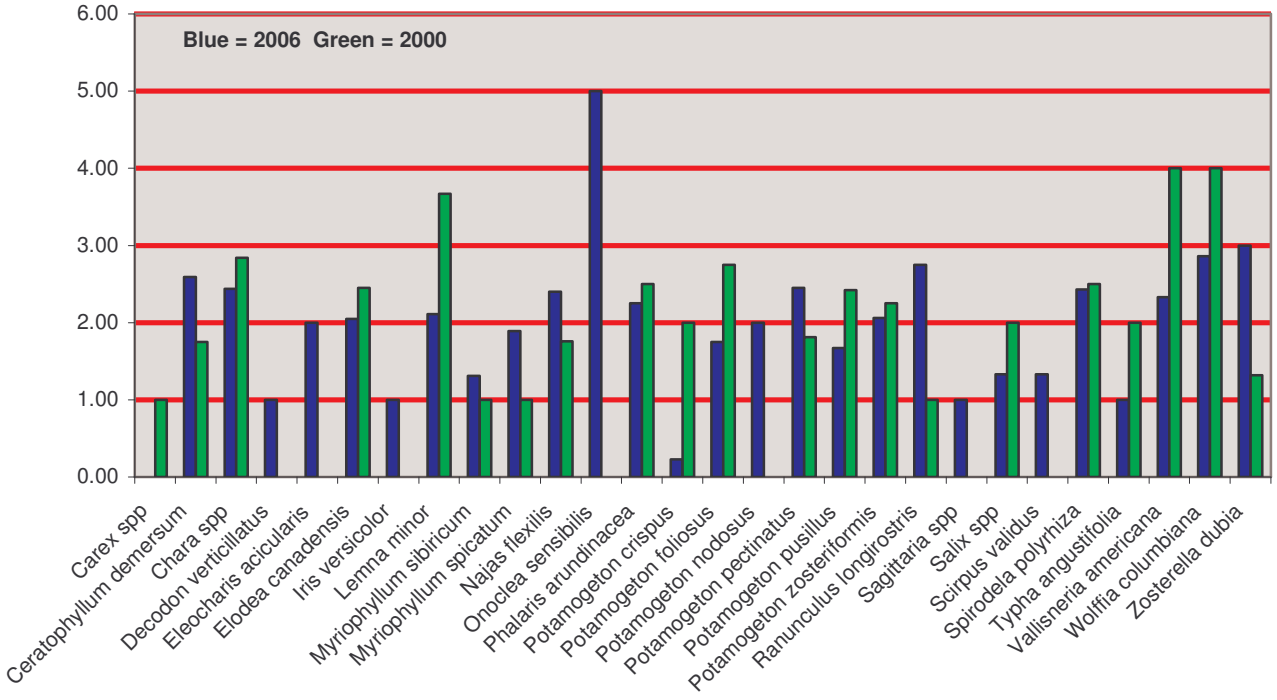
In Depth Zone 3 (5'-10') and Depth Zone 4 (10'-20'), *Potamogeton nodusus* and *Potamogeton pectinatus* tied, with 1.56 in Zone 3 and 1.73 in Zone 4.

Chart 2: Mean Density



However, when looking at the mean density where present, several plants had a more than average density of occurrence: *Ceratophyllum demersum; Chara* spp*; Elodea canadensis; Lemna minor; Najas flexilis; Onoclea sensibilis; Potamogeton pectinatus; Potamogeten zosteriformis; Ranunculus longirostris; Spirodela polyrhiza; Vallisneria americana; Wolffia columbiana;* and *Zosterella dubia.* 2 of these plants are emergent; 3 are free-floating; and 8 are submergent plants. These figures indicate several species in the lake have higher than average growth form density that can interfere with fish habitat and recreational use.

Chart 2A: Mean Density Where Present

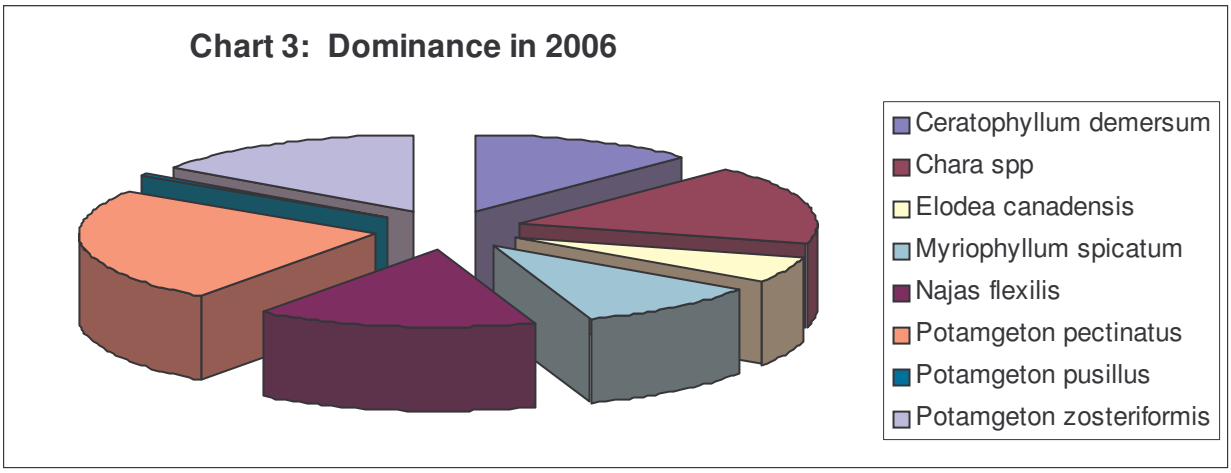


The 2000 figures show, as did the 2006 figures, that many of the plants have more than average density at the sites at which they occur. In other words, where aquatic plants are present, they often occur at higher than desired densities. In 2000, those included *Ceratophyllum demersum, Chara* spp*, Elodea canadensis, Lemna minor, Phalaris arundinacea, Potamogeton foliosus, Potamogeton pectinatus, Ranunculus longirostris, Spirodela polyrhiza, Vallisneria americana* and *Wolffia columbiana.* There were two more species at higher than average density where present in 2006 than in 2000. Many of the same species—*Ceratophyllum demersum, Chara* spp.*, Elodea canadensis, Lemna minor, Potamoeton pectinatus, Spirodela polyrhiza, Vallisneria americana,* and *Wolffia columbiana*—occurred at high densities where present in both years.

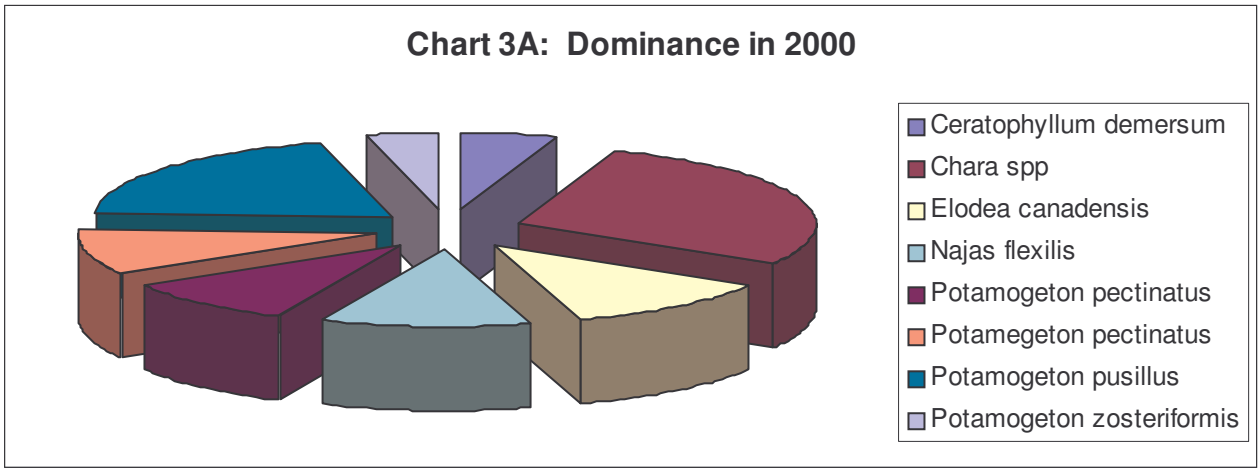
DOMINANCE

Relative frequency and relative density are combined into a dominance value that demonstrates how dominant a species is within its aquatic plant community. Based on dominance value, *Potamogeton pectinatus* was the dominant aquatic "plant" species in Arrowhead Lake. Sub-dominant were *Najas flexilis* and *Chara* spp,.and *Potamogeton zosteriformis.* *Myriphyllum spicatum*, *Phalaris arundinacea* and *Potamogeton crispus*, the exotics found Arrowhead Lake, were not present in high frequency, high density or high dominance.

Chara spp was dominant in Depth Zone 1. *Potamogeton nodosus* dominated Depth Zone 2, with *Najas flexilis* sub-dominant. *Potamogeton pectinatus* was dominant in Depth Zone 3 and Depth Zone 4.



Chara spp., *Najas flexilis* and *Potamogeton pectinatus* were dominant in both 2000 and 2006. Both *Chara* spp. increased substantially in its dominance. *Najas flexilis* increased somewhat, and *Potamogeton pectinatus* showed only a slight increase.



DISTRIBUTION

Aquatic plants occurred at 90.8% of the sample sites in Arrowhead Lake to a maximum rooting depth of 16' in 2006. In 2000, aquatic plant occurred at 80.7% of the sample sites, with a maximum rooting depth of 15'. Free-floating plants were found in three depth zones in 2006; they were found only in the shallowest zone in 2000. Filamentous algae were found in all sampling zones in both years.

Secchi disc readings are used to predict maximum rooting depth for plants in a lake (Dunst, 1982). Based on the summer 2004-2006 Secchi disc readings, the predicted maximum rooting depth in Arrowhead Lake would be **10.23 feet.** During the 2006 aquatic plant survey, rooted plants were found at a depth of **16'**, i.e., rooted plants were at a depth substantially more than that to be expected by Dunst calculations. This may be due to greater water clarity early in the summer when plant growth is starting.

In 2006, the 1.5'-5' depth zone (Zone 2) produced the highest total occurrence of plant growth, followed by Depth Zone 1, then Depth Zone 3, then a sharp drop to occurrence frequency in Depth Zone 4. The same order was followed with aquatic plant occurrence density.

Chart 5: Total Occurrence by Depth

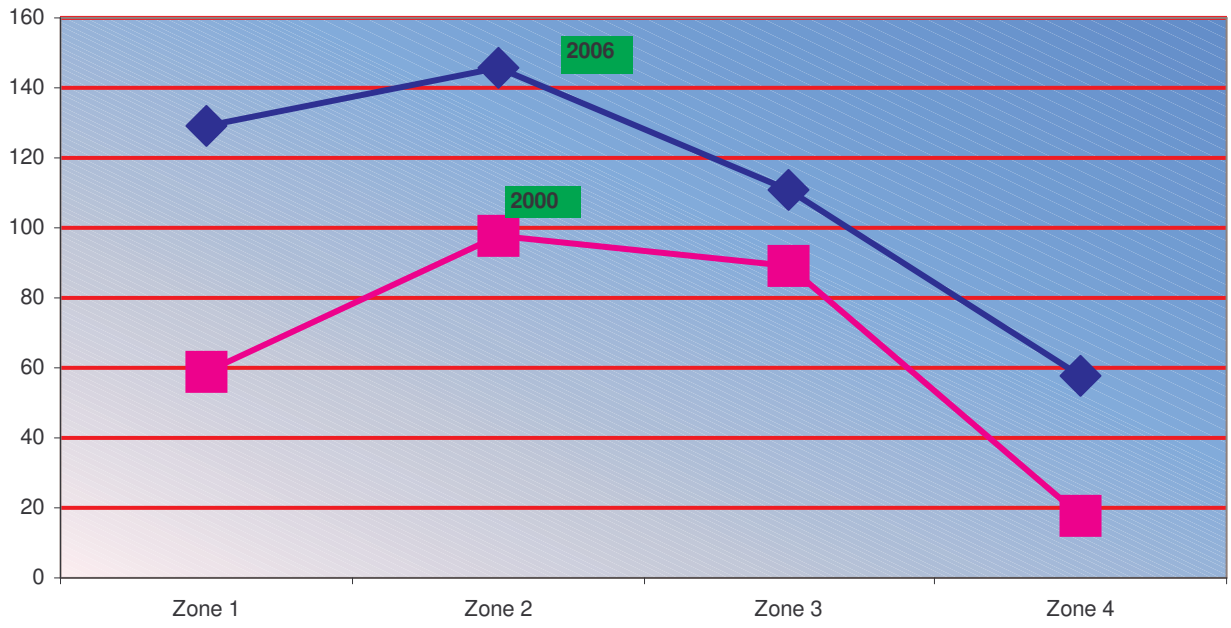


Chart 5: Total Density by Depth

As the above charts show, both total occurrence and total density were substantially increased in 2006, compared to 2000. Similarly, species richness increased in 2006 compared to 2000. In each year, the 1.5-5' depth zone (Zone 2) had the highest species richness, and the 10'-20' depth zone (Zone 4) had the lowest. In 2006, the shallowest depth zone had the next to highest species richness, with the 5'-10' depth zone having the next to lowest. Those were reversed in 2000.

	2006	2000
Zone 1	4	1.97
Zone 2	4.53	3.27
Zone 3	3.47	2.86
Zone 4	2.76	0.9
Overall	3.76	2.88

THE COMMUNITY

The Simpson's Diversity Index in 2006 for Arrowhead Lake was .91, showing good species diversity. This was up slightly from the 2000 index of .89. A rating of 1.0 would mean that each plant in the lake was a different species (the most diversity achievable). This places it in the upper quartile for Simpson's Diversity Index readings for both North Central Hardwood Forest and all Wisconsin lakes. The AMCI for Arrowhead Lake is 56, placing it in the average range for North Central Wisconsin Lakes and all Wisconsin Lakes. The AMCI in 2000 was also 56. In 2000, there were fewer species and fewer sensitive plants, but more submergent plants.

Table 5: Aquatic Macrophyte Community Index-2006 & 2000

Aquatic Macrophyte Community Index				
	2006	2006	2000	2000
	results	value	results	value
rooting depth	16'	9	15'	9
% littoral zone vegetated	90.80%	10	80.70%	10
% submersed plants	62%	6	73%	9
% sensitive plants	17%	7	12%	6
# taxa found	26	10	22	9
% exotic species	10%	5	9%	5
Simpson's Index	0.91	9	0.89	8
		56		56

The presence of several invasive, exotic species could be a significant factor in the future. Currently, none of the exotic species appear to be taking over the aquatic plant community, but both *Myriophyllum spicatum* and *Potamogeton crispus* had occurrence frequencies of over 20% in 2006. These species should be monitored, since their tenacity and ability to spread to large areas fairly quickly could make them a danger to the diversity of Arrowhead Lake's current aquatic plant community. *Myriophyllum spicatum* is of particular concern because it occurred

much more often in 2006 than it did in 2000 (36.92% in 2006 compared to 1.83% in 2000).

An Average Coefficient of Conservatism and a Floristic Quality Index calculation were performed on the field results in both years. Technically, the Average Coefficient of Conservatism measures the community's sensitivity to disturbance, while the Floristic Quality Index measures the community's closeness to an undisturbed condition. Indirectly, they measure past and/or current disturbance to the particular community.

Previously, a value was assigned to all plants known in Wisconsin to categorize their probability of occurring in an undisturbed habitat. This value is called the plant's Coefficient of Conservatism. A score of 0 indicates a native or alien opportunistic invasive plant. Plants with a value of 1 to 3 are widespread native plants. Values of 4 to 6 describe native plants found most commonly in early successional ecosystem. Plants scoring 6 to 8 are native plants found in stable climax conditions. Finally, plants with a value of 9 or 10 are native plants found in areas of high quality and are often endangered or threatened. In other words, the lower the numerical value a plant has, the more likely it is to be found in disturbed areas.

The Average Coefficient of Conservatism in Arrowhead Lake in 2006 was 4.58, similar to the 4.5 result from 2000. This puts Arrowhead Lake in the lowest quartile for Wisconsin Lakes (6.0) and for lakes in the North Central Hardwood Region (5.6). The aquatic plant community in Arrowhead Lake is in the category of those very tolerant of disturbance, probably due to selection by a series of past disturbances.

The Floristic Quality Index of the aquatic plant community in Arrowhead Lake of 23.34 is slightly above average for Wisconsin Lakes (22.2) and the North Central Hardwood Region (20.9). In 2000, it was 19.09, slightly below average, so the FQI has increased slightly since 2000. This suggests that the plant community in Arrowhead Lake is a little closer to an undisturbed condition than the average lake in Wisconsin overall and in the North Central Hardwood Region. Using either scale, the aquatic plant community in Arrowhead Lake has been impacted by at least an average amount of disturbance.

"Disturbance" is a term that covers many disruptions to a natural community. It includes physical disturbances to plant beds such as boat traffic, plant harvesting, chemical treatments, dock and other structure placements, shoreline development and fluctuating water levels. Indirect disturbances like sedimentation, erosion, increased algal growth, and other water quality impacts will also negatively affect an aquatic plant community. Biological disturbances such as the introduction of non-native and/or invasive species (such as the Eurasian Watermilfoil, Reed Canarygrass and Curly-Leaf Pondweed found here), destruction of plant beds, or changes in aquatic wildlife can also negatively impact an aquatic plant community. Shore development and sediment deposition can also reduce the quality of the aquatic plant community.

Very few of the sample transects had an entirely native shore; most sites had some disturbance by humans. In fact, of the 32 transects in Arrowhead Lake, only 4 didn't have significant disturbance.

	Natural	Disturbed
Number of species	25	30
FQI	22.4	23.92
Average Coef. Of Cons	4.48	4.37
Simpson's Index	0.93	0.89
AMCI	51	50
Filamentous algae	100%	100%

Using these figures, the disturbed shores actually had higher scores for FQI and species number, but the natural shores have a higher coefficient of Conservatism, higher Simpson's Diversity Index, and higher Aquatic Macrophyte Community Index. The high amount of disturbance in the lake overall probably explains this low level of differentiation between natural and disturbed shores.

IV. DISCUSSION

Based on water clarity, chlorophyll and phosphorus data, Arrowhead Lake is a mesotrophic impoundment lake with good water clarity and fair to good water quality. This trophic state should support substantial plant growth and occasional algal blooms.

Sufficient nutrients (trophic state), hard water, good water clarity, shallow lake, and nutrient-rich inputs from increased shore development at Arrowhead Lake favor plant growth. Despite the sometime limiting effect of sand sediments on aquatic plant growth, 89% of the lake is vegetated, suggesting that even the sand sediments in Arrowhead Lake hold sufficient nutrients to maintain aquatic plant growth.

Historically, many aquatic plant treatments in Arrowhead Lake were chemical. There has been mechanical harvesting to try to reduce plant growth in the last 10

years. A continued regular schedule and pattern of machine harvesting will help in removing vegetation from the lake and may somewhat help with nutrient reduction. The harvesting should also be designed to set back the growth of Eurasian Watermilfoil, not spread it further. It might also help to skim off the high density of filamentous algae and floating-leaf plants.

The lake does have a mixture of emergent, free-floating, and submerged plants. Of the 28 species found in Arrowhead Lake, 25 were native and 3 were exotic invasives. In the native plant category, 9 were emergent, 3 were free-floating plants, and 13 were submergent species. Three exotic invasives, *Myriophyllum spicatum* (Eurasian Watermilfoil), *Phalaris arundinacea* (Reed Canarygrass) and *Potamogeton crispus* (Curly-Leaf Pondweed) were found.

Potamogeton pectinatus was the most frequently-occurring plant in Arrowhead Lake in 2006 (58.46% frequency). No other species reached a frequency of 50% or greater. Next closest in frequency of occurrence were *Chara* spp (40.00%), *Potamogeton zosteriformis* (38.46%), and *Najas flexilis* (36.92%).

Potamogeton pectinatus was the densest plant in Arrowhead Lake, with a mean density of 1.43 (on a scale of 1 to 4) and a mean density where present of 2.45 (more than average density). None of the aquatic vegetation had a mean density of over 2.0, meaning none occurred at more than average density in the lake overall. There were no species at more than average density in any of the depth zones either. However, when looking at the "mean density where present", several plants had a more than average form of growth: *Ceratophyllum demersum; Chara* spp*; Elodea canadensis; Lemna minor; Najas flexilis; Onoclea sensibilis; Potamogeton pectinatus; Potamogeten zosteriformis; Ranunculus*

longirostris; Spirodela polyrhiza; Vallisneria americana; Wolffia columbiana; and *Zosterella dubia.*

There a few areas of native vegetation and wetland shores on the lake that should be preserved as they are to maintain habitat and to serve as a buffer for that area. Studies have suggested that runoff from such land is substantially less than that of developed areas. There are also some areas of deep erosion on steep banks that need to be addressed to prevent tree fall (and related root ball removal from bank) and bank preservation.

The Simpson's Diversity Index Arrowhead Lake was .91, indicating good species diversity. A rating of 1.0 would mean that each plant in the lake was a different species (the most diversity achievable). This places it in the upper quartile for Simpson's Diversity Index readings for both North Central Hardwood Forest and all Wisconsin lakes. The AMCI for Arrowhead Lake is 56, placing it in the average range for North Central Wisconsin Lakes and all Wisconsin Lakes.

Native herbaceous vegetation was the shoreline cover with highest percent of frequency (56.67%), but wooded vegetation had the highest coverage amount (30.00%), although cultivated lawn was close behind with 29% coverage. Some type of native vegetated shoreline covered 48.00% of the lake shoreline. But disturbed sites, such as those with traditional lawn, rock/riprap, hard structures and pavement, were also frequent, covering over 40.34% of the shoreline. Bare unprotected or eroded soil was found (11.66% coverage). Overall, 52.00% of Arrowhead Lake's shore has some kind of disturbed situation. These conditions offer little protection for water quality and have significant potential to negatively

impact Arrowhead Lake's water by increased runoff (including lawn fertilizers, pet waste, pesticides) and shore erosion.

The AMCI for both 2000 and 2006 is 56, but the Average Coefficient of Conservatism is lower than it was in 1979. Species Richness and the Floristic Quality Index went up between 2002 and 2006, as did the Simpson's Index of Diversity. But the Floristic Quality Index in 1979 was between the 2000 and 2006 scores. It appears, even using the limited information from 1979 and 1992, that increase in these figures may not necessarily indicate an ongoing increase in the quality of the aquatic plant community.

Further, when calculating the coefficient of similarity between the 2000 and 2006 surveys, they score as statistically dissimilar. Based on frequency of occurrence, the aquatic plant communities of the two years are only 53% similar. Based on relative frequency, they are 57% similar. Similarity percentages of 75% or more are considered statistically similar; obviously, Arrowhead Lake percentages are far from that.

	Changes in the Macrophyte Community			
Arrowhead	2000	2006	Change	%Change
Number of Species	18	26	8.00	**44.4%**
Maximum Rooting Depth	15.0	16.0	1.00	**6.7%**
% of Littoral Zone Unvegetated	19.30%	9.20%	-10.10	-52.33%

%Sites/Emergents	6.82%	5.93%	-0.01	-13.0%
%Sites/Free-floating	6.82%	11.86%	0.05	**73.9%**
%Sites/Submergents	100.00%	100.00%	0.00	0.0%
%Sites/Floating-leaf	0.00%	0.00%	0.00	
Simpson's Diversity Index	0.89	0.91	0.02	**2.2%**
Species Richness	2.88	3.86	0.98	**34.0%**
Floristic Quality	19.09	23.34	4.25	**22.3%**
Average Coefficient of Conservatism	4.5	4.58	0.08	**1.8%**
AMCI Index	56	56	0.00	**0.0%**

It is worth noting that the report on the 2000 aquatic plant surveys mentioned the absence of emergent plants in Arrowhead Lake. The 2006 survey shows that emergent plants seem to be "coming back", i.e., are re-establishing in Arrowhead Lake. However, the occurrence of filamentous algae has also increased since 2000, as had the total occurrence and total density of aquatic plant growth in all depth zones. Further, the increase in free-floating plants may be due to increased nutrient loading.

The chart below outlines the changes in specific plant species between 2000 and 2006. Plants such as *Ceratophyllum demersum* and *Potamogeton pectinatus* are among those most tolerant of disturbances and poor water clarity. The increase in those plants may be indicative of ongoing disturbance in the lake overall. There was 5% increase in the occurrence of sensitive species. Exotic species stayed about the same occurrence frequency overall (9% in 2000 vs. 10% in 2006). Arrowhead Lake did increase in emergent species, although that tended to be

localized, but continues to be low in floating-leaf plants that provide habitat for fish and invertebrates.

	Changes in Aquatic Plant Species				
Species		**2000**	**2006**	Year1-2	% Change
Ceratophyllum demersum	Frequency	1.83%	**28.46%**	26.63%	93.6%
	Mean Density	0.19	**0.75**	0.56	74.7%
	Dom. Value	0.08	**0.18**	0.10	55.6%
Chara spp	Frequency	**44.95%**	44.07%	0.88%	-2.0%
	Mean Density	**1.28**	0.98	0.30	-30.6%
	Dom. Value	**0.44**	0.24	0.20	-83.3%
Elodea canadensis	Frequency	**20.18%**	14.62%	5.56%	-38.0%
	Mean Density	**0.5**	0.3	0.20	-66.7%
	Dom. Value	**0.18**	0.08	0.10	-125.0%
Lemna minor	Frequency	2.75%	**6.92%**	4.17%	60.3%
	Mean Density	0.1	**0.15**	0.05	33.3%
	Dom. Value	0.03	**0.04**	0.01	25.0%
Myriophyllum sibiricum	Frequency	1.83%	**21.54%**	19.71%	91.5%
	Density	0.02	**0.29**	0.27	93.1%
	Imp. Val.	0.01	**0.1**	0.09	900.0%
Myriophyllum spicatum	Frequency	1.83%	**27.69%**	25.86%	93.4%
	Density	0.02	**0.52**	0.50	96.2%
	Imp. Val.	0.1	**0.15**	0.05	33.3%
Najas flexilis	Frequency	22.94%	**36.92%**	13.98%	37.9%
	Density	0.4	**0.88**	0.48	54.5%
	Imp. Val.	0.18	**0.22**	0.04	18.2%
Phalaris arundinacea	Frequency	1.83%	**3.08%**	1.25%	40.6%

	Density	0.05	**0.07**	0.02	28.6%
	Imp. Val.	0.02	**0.02**	0.00	0.0%
Potamogeton crispus	Frequency	16.51%	**23.85%**	7.34%	30.8%
	Density	0.33	**0.35**	0.02	6.1%
	Imp. Val.	0.13	**0.07**	0.06	46.2%
Potamogeton foliosus	Frequency	**22.02%**	3.08%	-18.94%	-86.0%
	Density	**0.61**	0.05	-0.56	-91.8%
	Imp. Val.	**0.21**	0.02	-0.19	-90.5%
Potamogeton pectinatus	Frequency	19.27%	**58.46%**	39.19%	203.4%
	Density	0.35	**1.43**	1.08	308.6%
	Imp. Val.	0.15	**0.04**	-0.11	-73.3%
Potamogeton pusillus	Frequency	**34.86%**	2.31%	-32.55%	-93.4%
	Density	**0.84**	0.04	-0.80	-95.2%
	Imp. Val.	**0.31**	0.01	-0.30	-96.8%
Potamogeton zosteriformis	Frequency	7.34%	**38.46%**	31.12%	424.0%
	Density	0.17	**0.79**	0.62	364.7%
	Imp. Val.	0.06	**0.12**	0.06	100.0%
Ranunculus longirostris	Frequency	0.92%	**3.08%**	2.16%	234.8%
	Density	0.01	**0.08**	0.07	700.0%
	Imp. Val.	0.01	**0.01**	0.00	0.0%
Spirodela polyrhiza	Frequency	1.83%	**5.38%**	3.55%	194.0%
	Density	0.05	**0.13**	0.08	160.0%
	Imp. Val.	0.02	**0.03**	0.01	50.0%
Typha latifolia	Frequency	**0.92%**	0.77%	-0.15%	-16.3%
	Density	**0.02**	0	-0.02	-100.0%
	Imp. Val.	**0.01**	0	-0.01	-100.0%
Vallisneria americana	Frequency	0.92%	**4.62%**	3.70%	402.2%

	Density	0.04	**0.11**	0.07	175.0%
	Imp. Val.	0.01	**0.03**	0.02	200.0%
Wolffia columbiana	Frequency	0.92%	**10.77%**	9.85%	1070.7%
	Density	0.04	**0.31**	0.27	675.0%
	Imp. Val.	0.01	**0.07**	0.06	600.0%
Zosterella dubia	Frequency	**17.43%**	0.77%	-16.66%	-95.6%
	Density	**0.23**	0.02	-0.21	-91.3%
	Imp. Val.	**0.12**	0.01	-0.11	-91.7%
Carex spp	Frequency	**1.83%**	0	0.02	-100.0%
	Density	**0**	0	0.00	
	Imp. Val.	**0.01**	0	0.01	-100.0%
Decodon verticillatus	Frequency	0	**0.77%**	0.0077	100.0%
	Density		**0**	0	0.0%
	Imp. Val.		**0**	0	0.0%
Eloeocharis acicularis	Frequency	0	**1.54%**	0.0154	100.0%
	Density	0	**0**	0	0.0%
	Imp. Val.	0	**0.01**	0.01	100.0%
Iris versicolor	Frequency	0	**0.77%**	0.0077	100.0%
	Density	0	**0**	0	0.0%
	Imp. Val.	0	**0**	0	0.0%
Onoclea sensibilis	Frequency	0	**0.77%**	0.0077	100.0%
	Density	0	**0.01**	0.01	100.0%
	Imp. Val.	0	**0.01**	0.01	100.0%
Potamogeton nodosus	Frequency	0	**1.54%**	0.0154	100.0%
	Density	0	**0.19**	0.19	100.0%
	Imp. Val.	0	**0.2**	0.2	100.0%
Sagittaria spp	Frequency	0	**0.77%**	0.0077	100.0%
	Density	0	**0**	0	0.0%

	Imp. Val.	0	**0.01**	0.01	100.0%

V. CONCLUSIONS

Arrowhead Lake is a mesotrophic to oligotrophic impoundment with good water quality and water clarity. The Average Coefficient of Conservatism of the aquatic plant community in Arrowhead Lake is in the lowest quartile for Wisconsin lakes and for lakes in the North Central Hardwood region, but the lake has a slightly above average Floristic Quality Index. The AMCI is in the average range for both North Central Hardwood Region and all Wisconsin lakes, indicating an aquatic plant community of average quality. Filamentous algae are abundant and have increased since 2000. Structurally, the aquatic plant community contains emergent plants, free-floating plants, floating-leaf rooted plants and submergent plants, with the 1.5'-5' depth zone supporting the greatest amount of plant growth.

When the aquatic plant survey was performed in 2006, nearly 91% of the littoral zone was vegetated. The potential for plant growth at all depths of the lake is present, even with many of the lake sediments sandy. This growth percent is slightly over the recommended vegetation percentage for best fishing (50%-85%).

Potamogeton pectinatus was the most frequently-occurring plant in Arrowhead Lake in 2006 (58.46% frequency). Next closest in frequency of occurrence were *Chara* spp (40.00%), *Potamogeton zosteriformis* (38.46%), and *Najas flexilis* (36.92%). *Potamogeton pectinatus* was the densest plant in Arrowhead Lake, with a mean density of 1.43 (on a scale of 1 to 4) and a mean density where present of 2.45 (more than average density). None of the aquatic vegetation had a

mean density of over 2.0, meaning none occurred at more than average density in the lake overall. However, when looking at the mean density where present, 13 plants had a more than average density of occurrence, indicating the potential of the lake to produce dense aquatic vegetation that could create some problems in lake management.

A healthy and diverse aquatic plant community plays a vital role within the lake ecosystem. Plants help improve water quality by trapping nutrients, debris and pollutants in the water body; by absorbing and/or breaking down some pollutants; by reducing shore erosion by decreasing wave action and stabilizing shorelines and lake bottoms; and by tying-up nutrients that would otherwise be available for algae blooms. Aquatic plants provide valuable habitat resources for fish and wildlife, often being the base level for the multi-level food chain in the lake ecosystem, and also produce oxygen needed by animals.

Further, a healthy and diverse aquatic plant community can better resist the invasion of species (native and non-native) that might otherwise "take over" and create a lower quality aquatic plant community. A well-established and diverse plant community of natives can help check the growth of more tolerant (and less desirable) plants that would otherwise crowd out some of the more sensitive species, thus reducing diversity.

Vegetated lake bottoms support larger and more diverse invertebrate populations that in turn support larger and more diverse fish and wildlife populations (Engel, 1985). Also, a mixed stand of aquatic macrophytes (plants) supports 3 to 8 times more invertebrates and fish than do monocultural stands (Engel, 1990). A diverse plant community creates more microhabitats for the preferences of more species.

MANAGEMENT RECOMMENDATIONS

(1) Because the plant cover in the littoral zone of Arrowhead Lake is over the ideal (25%-85%) coverage for balanced fishery and there are some areas with more than average plant density, continued harvesting to open fishing lanes should occur in some areas. Removal should occur by hand in the shallower areas to be sure that entire plants are removed and to minimize the amount of disturbance to the sediment.

(2) Natural shoreline restoration and erosion control in several areas is needed, especially on some bare steep banks. If trees fall at these eroded sites due to continued erosion, large portions of the banks will fall with them.

(3) To protect water quality, a buffer area of native plants needs to be restored on those many sites that now have seawalls or have traditional lawns mowed to the water's edge.

(4) The Tri-Lakes Management District and the Arrowhead Lake Association should continue to cooperate with the WDNR to monitor and, if possible, control the zebra mussel infestation in the lake to protect the aquatic plant community.

(5) Stormwater management of the many impervious surfaces around the lake is essential to maintain the current quality of the lake water and prevent further degradation.

(6) No lawn chemicals should be used on properties around the lake. If they must be used, they should be used no closer than 50' to the shore.

(7) The aquatic plant management plan should be reviewed annually. Mechanical harvesting plans should continue target harvesting for Eurasian Watermilfoil (EWM) and include target harvesting for Curly-Lead Pondweed to prevent further spread.

(8) The Arrowhead Lake Association may want to continue to apply for grants from the Wisconsin Department of Natural Resources to help defray the cost of aquatic plant management.

(9) No broad-scale chemical treatments of aquatic plant growth are recommended due to the undesirable side-effects of such treatments, including increased nutrients from decaying plant material and decreased dissolved oxygen and opening up more areas to the invasion of EWM.

(10) Fallen trees should be left at the shoreline or in the water.

(11) The Tri-Lakes Management District conducted water quality monitoring for several years, but has decreased its involvement during 2004-2006 when Adams Land & Water Conservation Department was doing more intense monitoring as part of a Lake Classification Grant. Monitoring by the Lake District or through the DNR Self-Help Monitoring Program should be restarted.

(12) Arrowhead Lake residents should identify, cooperate with and participate in watershed programs that will reduce nutrient and sediment inputs. Nutrients appear to have increased within the lake district, so residents must take steps to reduce their nutrient inputs.

(13) No drawdowns of water level except for DNR-approved purposes should occur. Drawdowns in the past have increased nutrient inputs to the lake through ground water; these increased nutrients are feeding the algae growth.

(14) The few sites where there is undisturbed shore, mostly in designated conservancy areas, should be maintained and left undisturbed.

(15) The Tri-Lakes Management District should make sure that its lake management plan takes into account all inputs from both the Arrowhead Lake surface ground watershed and inputs from Camelot & Sherwood Lakes, and addresses the concerns of this larger lake community.

(16) Cooperation with the Adams County Parks Department in keeping the boat ramp and swimming beach in safe condition should help reduce any negative impacts caused by the heavy use of these public areas.

(17) Pursue installation of sewage system around the lake to reduce nutrient input from the lakeshores. Reducing nutrient inputs by residents needs to occur before asking watershed residents to reduce theirs.

LITERATURE CITED

Dennison, W., R. Orth, K. Moore, J. Stevenson, V. Carter, S. Kollar, P. Bergstrom and R. Batuik. 1993. Assessing water quality with submersed vegetation. BioScience 43(2):86-94.

Duarte, Carlos M. and Jacob Kalff. 1986. Littoral slope as a predictor of the maximum biomass of submerged macrophyte communities. Limnol.Oceanogr. 31(5):1072-1080.

Dunst, R.C. 1982. Sediment problems and lake restoration in Wisconsin. Environmental International 7:87-92.

Engel, Sandy. 1985. Aquatic community interactions of submerged macrophytes. Wisconsin Department of Natural Resources, Technical Bulletin #156. Madison, WI.

Gleason, H, and A. Cronquist. 1991. Manual of Vascular Plants of Northeastern United States and Adjacent Canada (2nd Edition). New York Botanical Gardens, N.Y.

Jessen, Robert, and Richard Lound. 1962. An evaluation of a survey technique for submerged aquatic plants. Minnesota Department of Conservatism. Game Investigational Report No. 6.

Nichols, Stanley. 1998. Floristic quality assessment of Wisconsin lake plant communities with example applications. Journal of Lake and Reservoir Management 15(2):133-141.

Nichols, S., S. Weber and B. Shaw. 2000. A proposed aquatic plant community biotic index for Wisconsin lakes. Environmental Management 26(5):491-502.

Shaw, B., C. Mechenich and L. Klessig. 1993. Understanding Lake Data. University of Wisconsin-Extension. Madison, WI.

PLANT MAPS FOR ARROWHEAD LAKE 2006

Emergent Aquatic Plants in Arrowhead Lake 2006

RE:11/06

Emergent Aquatic Plants Found 2006

N
W E
S

Exotic Aquatic Vegetation in Arrowhead Lake 2006

RE:11/06

Exotic Aquatic Invasive Plants Found 2006

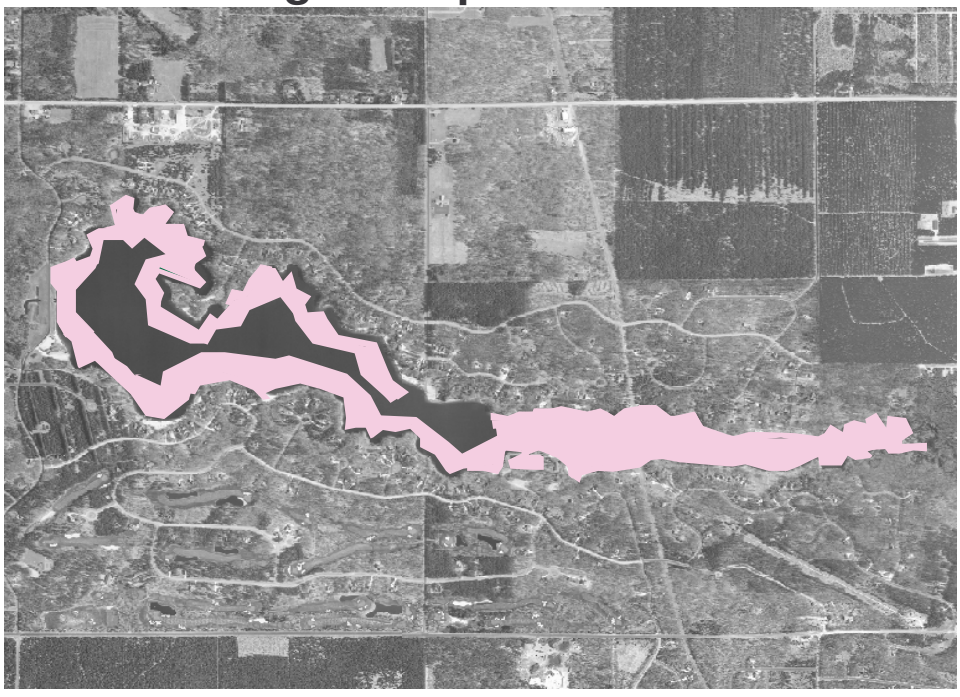
N
W E
S

Floating Plants in Arrowhead Lake 2006

RE:11/06

Floating Plants Found 2006

Submergent Aquatic Plants 2006



RE:11/06

Submergent Plants Found 2006